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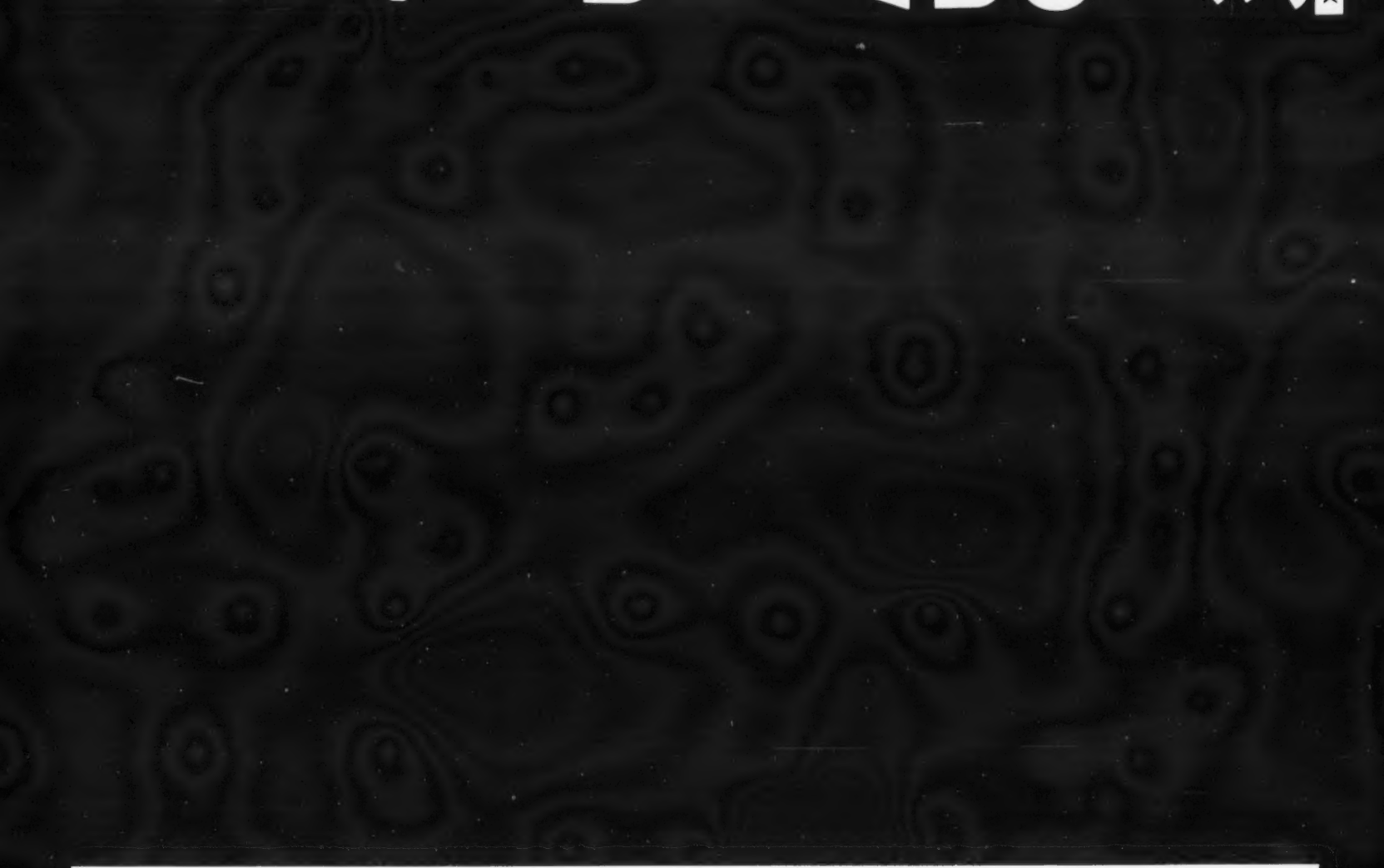

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RADIO ASTRONOMY IN AUSTRALIA

BY J. L. PAWSEY*

INTRODUCTION

RADIO astronomy has been studied extensively in Australia, mainly within the Radiophysics Laboratory in Sydney. The Commonwealth Observatory at Canberra has also contributed and the two bodies have collaborated at all times. The Radiophysics Laboratory is a division of the Commonwealth Scientific and Industrial Research Organization, (C.S.I.R.O.), and is broadly the Australian equivalent of the Radio and Electrical Engineering Division of the National Research Council of Canada. Since 1945 the Laboratory has been directed by Dr. E. G. Bowen, one of the original team which pioneered radar in England under Sir Robert Watson-Watt.

It is the policy of C.S.I.R.O. to encourage both fundamental and applied research within its divisions and the work on radio astronomy constitutes an important part of the organization's fundamental research.

This work began in the Radiophysics Laboratory immediately after World War II when radar equipment in which the Laboratory was interested was used to explore the newly-discovered radio emissions from the sun. New results were obtained at once and these were followed by more elaborate investigations. Interest spread to other fields of radio astronomy, pioneering discoveries were made, and these again were followed up.

As a result of this step by step process, the Laboratory's radio astronomy group has been concerned at various times with a broad range of topics: the moon, studied both by means of radio echoes and by its thermal radio emission; the sun, quiet and disturbed; "radio stars"; the distribution of radio frequency radiation from the galaxy, both continuous and line

*Assistant Chief of the Radiophysics Laboratory, Sydney, Australia, and has directed the Radio Astronomy research there since it began.

radiation; and the terrestrial ionosphere studied by means related to radio astronomy. It is not possible to cover all these diverse fields in this article and the account is restricted to some of the more interesting items on which work is now proceeding.

In this review of Australian work the references in the bibliography have been restricted to those of Australian contributors. Other contributors are mentioned in the text when this is desirable in order to present the Australian work in proper perspective.

Thermal Radio Waves from the Sun

It is natural to expect that radio waves might be emitted by the sun with an intensity corresponding roughly to 6000-degree black-body emission. Southworth's pioneer centimetre-wave-length observations at the Bell Telephone Laboratories supported this expectation. But in the first systematic series of observations on metre wave-lengths, commenced in 1945 in Sydney, Pawsey, McCready and Payne-Scott[1, 2] found a very different picture at 1.5 metres from that found by Southworth on centimetre wave-lengths. Not only were there substantial increases in intensity associated with sun-spots, which was known from the English wartime work of Hey, but the minimum intensities did not fall below a value corresponding to black-body emission of about a million degrees.

This observation was discussed with Martyn who explained it very satisfactorily.[3] He pointed out that radio waves at such a wave-length should come from the solar corona, which has a temperature of about a million degrees, rather than from the 6000-degree photosphere in which light chiefly originates. He was able to follow the region of origin of thermal radiation from the outer corona at wave-lengths of tens of metres to the mid-chromosphere at a few centimetres, and to make theoretical predictions concerning the intensity of the radiation which should be emitted thermally by the undisturbed sun at each wave-length. Incidentally he also predicted that the distribution of "brightness" at decimetre wave-lengths should show marked limb-brightening; the reverse of that observed optically. This result has not yet been confirmed by observation and is the subject of vigorous controversy. Martyn's treatment of the quiet sun was not rigorous; a more rigorous treatment has since been given by Smerd.[4]

The variability with time of solar emission complicated the comparison of theory and observation but it was shown by Pawsey and Yabsley[5] that at each wave-length in the wave-length range from one centimetre to four metres a base level of radiation existed which corresponded well with the theoretical prediction. It was concluded from these investigations that

solar radiation consists of various disturbed components which add to a base level due to thermal emission from the quiet sun.

With the thermal component identified, it should be possible to work back from the observed intensity values to obtain information concerning physical conditions in the solar atmosphere. A method has been devised by Piddington[6] which yields electron density and temperature in the chromosphere as a function of height. The similar problem in relation to the corona is not yet solved.

Turning now to the various disturbances, there is not yet agreement as to the mechanisms of origin of those observed on metre wave-lengths. There is, however, agreement on the probable mode of origin of the slow variations in intensity prominent on centimetre and decimetre wave-lengths. These are considered to be due to thermal emission from transient regions of excess density in the lower corona.

These regions which tend to occur over sun-spots may have temperatures up to 10^7 degrees Kelvin and are sometimes referred to as "hot spots". They have tentatively been identified with coronal condensations. This explanation was put forward independently in three countries, in Switzerland by Waldmeier, in France by Denisse and in Australia by Piddington and Minnett.[7]

Detailed information about the radiation from individual "hot spots" is now becoming available through the precise directional observations with the 32-element interferometer described below (see figures 6 and 7).

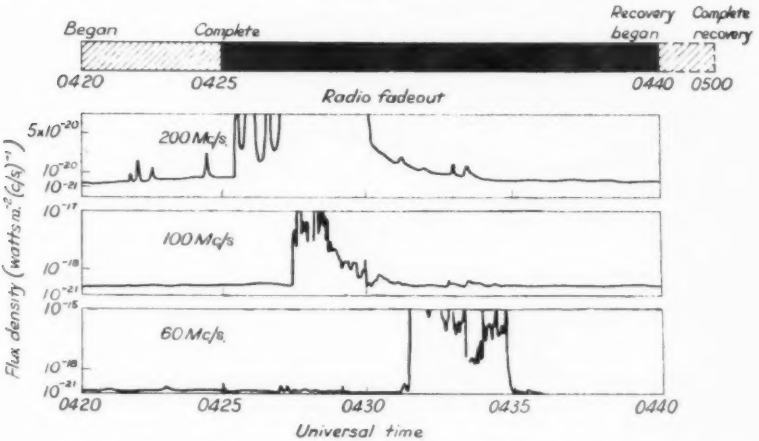

FIG. 1—The sequence of events during the record outburst of March 1947. (Payne-Scott, Yabsley and Bolton[8]).

Rapid development of our understanding of the phenomena is to be expected.

Solar Radio Outbursts and Terrestrial Magnetic Storms

One of the most interesting features of disturbed solar radio emission, discovered in England by Appleton and Hey, is its association with solar flares. At the time of a large flare an intense increase or "outburst" occurs which lasts for some minutes.

On March 8, 1947 an outburst was recorded at Sydney and Canberra simultaneously on three frequencies, 60, 100 and 200 mc./sec.[8] (see figure 1). Incidentally, the peak intensity on 60 mc./sec., off-scale at a flux density of 10^{-15} watts m.$^{-2}$ (c./s.)$^{-1}$, is the greatest ever recorded. It corresponds to black-body radiation from the whole disk of the sun at a temperature greater than 10^{13} degrees Kelvin. A striking feature of the record is the progressive time delay between the onset at different frequencies, high frequencies first, low frequencies last.

A subsequent series of observations by Wild and McCready[9, 10] of the dynamic spectra of solar radio disturbances in the frequency range 70 to 130 mc./sec. established the existence of a well-defined class of disturbance showing such systematic frequency delays. New equipment extending the frequency range to 40–220 mc./sec. has recently been completed and figure 2 illustrates the first outburst to be recorded.[11] This

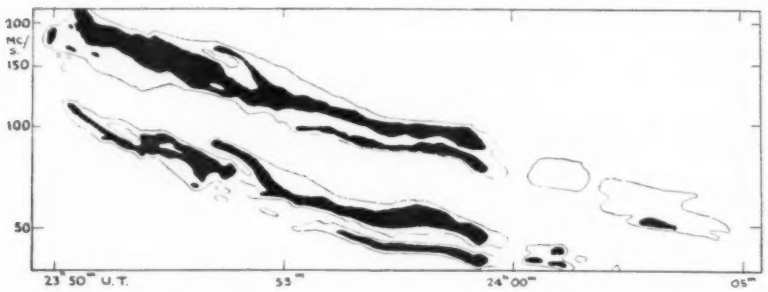

Fig. 2—The dynamic spectrum of the outburst of November 21, 1952. The two contours show intensity as a function of frequency and time and correspond to levels differing by a factor of four. (Wild, Murray and Rowe[11]).

shows the familiar frequency drift but also a new feature. It appears to consist of two disturbances at a two-to-one frequency interval, perhaps a fundamental and its second harmonic produced in a non-linear system.

Returning to the frequency drift shown by some, though not necessarily by all, outbursts, the probable explanation is in terms of a moving source in the solar atmosphere. Theory indicates that in the highly ionized atmosphere of the sun radiation should not be capable of propagation, and hence of escape, from below a level which depends on the electron density for the frequency concerned. This level is high in the corona for low frequencies (e.g. 60 mc./sec.) and falls with increasing frequency reaching the mid-chromosphere for frequencies of thousands of megacycles per second (wave-lengths of tens of centimetres). The frequency drift can be interpreted as a consequence of this escape limitation by supposing that the outburst is due to a moving disturbance in the solar atmosphere which moves upwards from low levels at which only high-frequency waves can escape, to high levels at which lower frequencies also can escape. On this interpretation the disturbances of figures 1 and 2 moved upwards in the solar atmosphere with velocities of about 500 kilometres per second. This velocity is also of the order of that of the solar corpuscles which are believed to be ejected at the time of great flares and which cause terrestrial aurorae and magnetic storms. It has been suggested that an outburst is due to the disturbance caused by the outward motion of such particles through the solar corona.

If the cause of the disturbance is actually moving it might be expected that the apparent position of the disturbance on the solar disk should also move. This expectation has been beautifully verified by Payne-Scott and Little[12] using the "swept-lobe" interferometer to be described in the next section. It was found that whereas the sources of most disturbances appear more or less fixed on the sun, those of outbursts show a rapid movement, generally away from the centre of the disk. The results of observations of intensity and position for a typical outburst are shown in figure 3. The apparent position of the source is seen to move about one solar radius in 10 minutes, which, on the assumption that the actual movement of the source is vertically upwards in the solar atmosphere, corresponds to a velocity of about 1500 kilometres per second.

These two independent means of observation both lead to a similar inference, a rapidly moving source in the solar atmosphere. So far it has not been possible to obtain observations by the two methods on the same outburst but the two equipments are now in operation and it is hoped that an outburst may soon be recorded simultaneously and that more complete optical observations may also be obtained. Meanwhile we are left with the intriguing hypothesis that in observing the radio outburst we are actually observing, by a mechanism which we do not yet understand, the expulsion of auroral corpuscles from the sun.

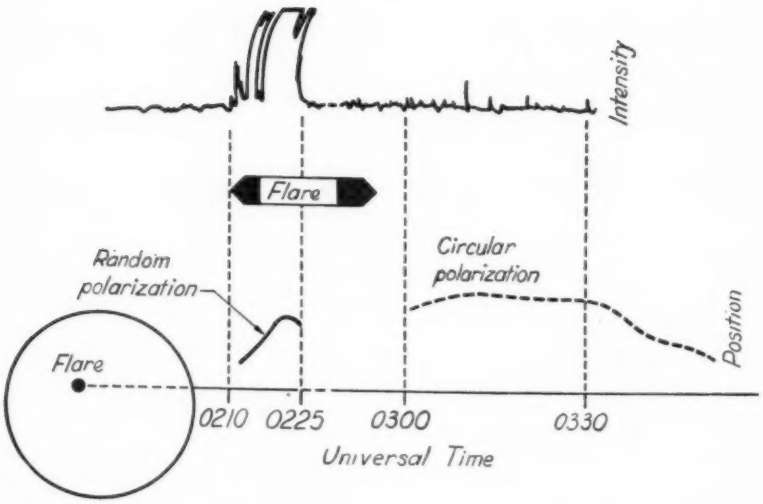

FIG. 3—The movement of the apparent source of a typical outburst together with the intensity and polarization changes. (Payne-Scott and Little[12]).

THE DEVELOPMENT OF INTERFEROMETERS TO GIVE HIGH ANGULAR DISCRIMINATION

Radio astronomy is severely handicapped in comparison with optical astronomy by the poor angular resolution of radio instruments due to diffraction limitations at wave-lengths which are a millionfold those of light. This limitation could in principle be overcome by the use of adequately large aerial systems, but in practice the sizes become prohibitively great. For example, at a wave-length of one metre the aerial diameter required to give a resolution of one minute of arc is 3.5 kilometres. In consequence, from the beginning much effort has been devoted to the development of methods which can give high angular discrimination without such large equipment.

The first step in this direction was made by McCready, Pawsey and Payne-Scott[2] in Sydney during January and February 1946. They used an interference method, analogous to the Lloyd's mirror method of optics, to determine the location on the solar disk of the source of 1.5-metre radiation. The rising sun was observed using a receiving aerial on a 250-foot cliff overlooking the sea to the east. It so happened that conditions were extraordinarily favourable owing to the presence of a great

sun-spot, the largest single spot ever photographed, which was accompanied by a very high level of solar radio emission. One of the records obtained is shown in figure 4(a). After sunrise the records shows clear-

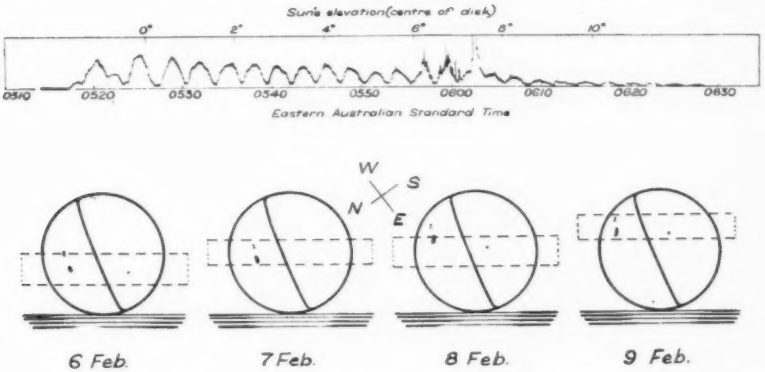

FIG. 4—The first radio-interferometer observations, made during the presence of the great sun-spot of February 1946. (a) One of the records. (b) The deduced position and upper limit to the width of the source of solar radio waves on successive days together with the sun-spot. (McCready, Pawsey and Payne-Scott[2]).

cut interference fringes which are due to interference between the direct ray and that reflected from the sea.

Two important conclusions were drawn from these records. The first concerned the size of the radio source. Because the minima of the records were effectively zeros, the size of the source must have been small with respect to the spacing between fringes. The second concerned the actual location of the source on the sun. From the timing of the minima, the source could be located on a line parallel to the horizon. Figure 4(b) shows the locations and upper limits of size obtained by this method on successive days together with the great sun-spot. It was concluded that the solar radio emission, at the time of this disturbance, originated mainly in a small disturbed region over the sun-spot.

Astronomers will recognize in this method an analogue of that used optically by Michelson to measure stellar diameters. An even closer analogue was utilized in Cambridge by Ryle and Vonberg when, during the presence of the next great sun-spot group in July 1946, they used an interferometer with two separate aerials spaced many wave-lengths apart on an east–west line. The latter form of interferometer has proved to be capable of giving more precise directional information owing to less troublesome refraction effects.

Returning to figure 4(a), we may note two limitations of the technique. The first is related to the irregularities on the record. The curve departs considerably from a smooth sine curve. These irregularities are due mainly to actual variations in solar emission, to the presence of many "bursts" of a few seconds duration, and it is clear that the method breaks down when applied to individual phenomena of such short duration. This difficulty has been overcome by Little and Payne-Scott[13] in the instrument they used for measurements, described in the preceding section, of the position of outbursts. It is a two-aerial interferometer analogous to that of Ryle and Vonberg but in which the interference fringes are caused, not by the slow drift of the position of the source due to the earth's rotation, but by a controlled phase change in the signal channels from the two aerials. This change can be rapid and in practice a complete fringe is produced and displayed on a cathode ray tube in 1/25 second. This process is repeated sufficiently frequently to give an essentially continuous record of source position and size.

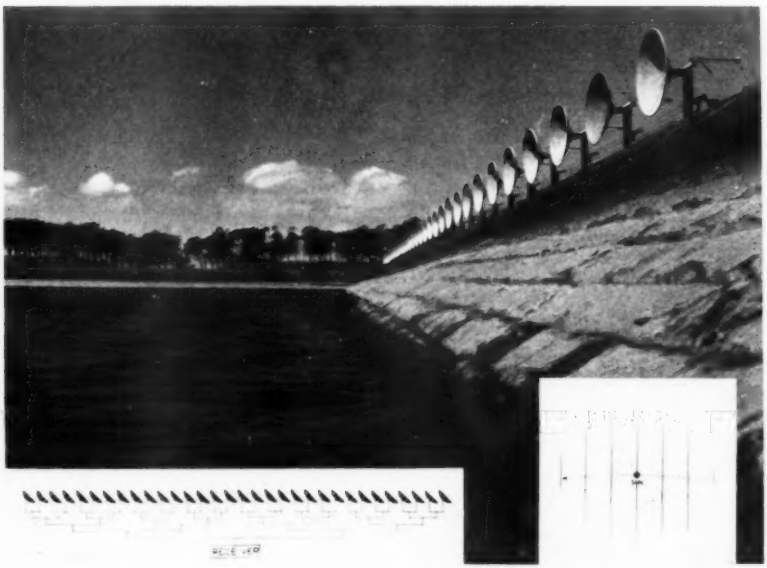

FIG. 5—The 32-element interferometer with a resolution of 3 minutes of arc at 21 cm. wave-length. Insets show, left, the aerial feed arrangements and, right, the polar diagram of the system in relation to the size of the sun. (Christiansen[15]).

The second limitation is not obvious from the figure. If the source is a single localized source we may obtain information about its size and position from the depth and timing of the minima, but if it is multiple or complex in shape the interpretation of the record may be ambiguous. If a series of such records were taken with different heights over the sea or, using the two aerial system, with a number of different aerial spacings, it would be possible to derive information about the shape of the source. This method has been used in Cambridge but it is cumbersome and basically ill suited to the determination of brightness distribution over an extended source. This limitation has proved not too troublesome at metre wave-lengths where it is usual for a disturbance on the sun to take the form of a single intense source. At decimetre wave-lengths, however, Christiansen, Yabsley and Mills[14] showed by simultaneous eclipse observations at Sydney, Melbourne and Strahan (Tasmania) that there are usually a number of bright areas distributed over the solar disk and connected in some way with sun-spots. Further investigation of this phenomenon required regular observations not possible by utilizing eclipses, and some new approach was clearly desirable.

The challenge was met by Christiansen[15] by the construction of a new form of multiple interferometer giving an actual beam with a width of only three minutes of arc. Working on a wave-length of 21 centimetres it extends over a length of more than 200 metres, but instead of a single aerial of this great size it employs the row of 32 two-metre diameter parabolic aerials illustrated in figure 5. This arrangement gives, not a pencil beam, but the series of knife-edge beams illustrated in the right-hand inset. The sun passes through each of these in turn and is scanned, strip wise, at each such passage.

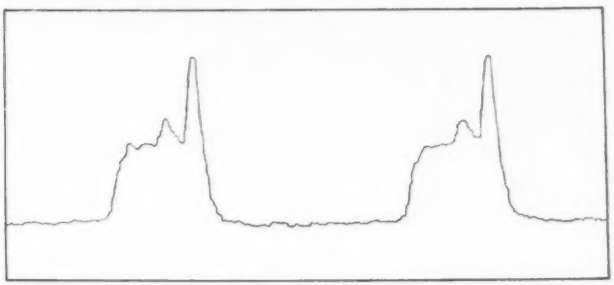

FIG. 6—Record obtained with the 32-element interferometer as the sun passed through two successive beams. (Christiansen[15]).

Figure 6 shows a record including two successive scans of the sun. The peaks indicate the presence of especially "bright" areas on the solar disk, the "hot spots" of the second section, and records extending over nearly a year are now available for study.

The peaks are superimposed on a general background due to thermal emission from the quiet sun. The relative contribution of "hot spots" and background cannot be determined from a single record but the background can be recognized as the minimum occurring over a sufficiently long time. The physical reality of this background is graphically displayed in figure 7 which is a mass-plot of records taken on successive

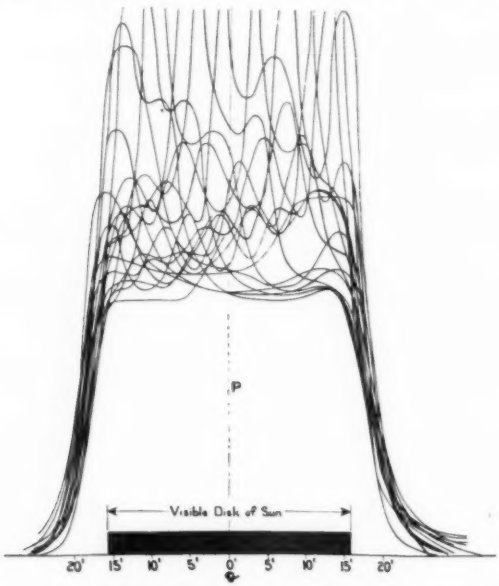

FIG. 7—Superposed records of solar brightness distribution obtained with the 32-element interferometer. The lower envelope delineates the distribution of the thermal component from the quiet sun. (Christiansen[15]).

days. The well defined lower envelope is the distribution due to the background emission. Incidentally, if the disk has anything like circular symmetry this distribution indicates marked limb-brightening at this wave-length. Further similar equipment is under construction which will determine the brightness distribution in the direction at right angles to the present one. When complete, simultaneous observations should settle the controversial question of limb-brightening unambiguously.

Radio Stars

The first clue to the existence of the class of objects known popularly as "radio stars" was obtained in England by Hey and his colleagues in 1946 when they noted that the cosmic radio waves from the direction of the constellation of Cygnus showed marked fluctuations. From the analogy of solar emission with its characteristic bursts, they inferred the existence of a discrete source of cosmic radio waves. Time has proved the analogy to be false but the inference to be right. In Sydney, Bolton and Stanley,[16] using the cliff-interferometer technique previously described, showed that there was indeed a strong concentrated source in the Cygnus region, of angular diameter less than their limit of resolution, eight minutes of arc, and nearly as intense as the quiet sun. Subsequent observations[17] showed that more such sources existed and that, within the limits of measurement, they showed no parallax. The sources do not belong to the solar system but to that of the fixed stars. Shortly after, a source even more intense than that in Cygnus was discovered in Cassiopeia by Ryle and Smith of Cambridge.

The existence of sources apparently at stellar distances but having an intensity comparable with the sun was surprising. Even more so was the fact that they were not associated with bright optical stars. The first information on the identity of the objects came from Bolton, Stanley and Slee[18] when they showed that three of the most intense coincided in position with nebulous objects. The most interesting was the Crab Nebula, an expanding shell of gas believed to be the remnant of a super-nova seen by Chinese astronomers in A.D. 1054. Very few similar objects exist in the sky and the identification seemed very plausible. Subsequent work continues to support it. The other two objects were catalogued as external galaxies, peculiar ones it is true, but at such distances that the required radio emission would be enormous. Meanwhile the identity of the first-discovered Cygnus source remained a mystery. The difficulty arose because of the mass of stars in the region of the source. The position of the radio source obtained in Sydney by Mills and Thomas[19] in 1951 had possible errors, so that the source could be anywhere within the "probable error rectangle." It must be remembered that it is most difficult to make the radio measurements precise and an accuracy of a few minutes of arc is the best that could be done for many years. Which one, if any, of the large numbers of stars within and in the vicinity of the probable error rectangle might be the radio source? Mills and Thomas provided a clue when they pointed out that there was one object in the field very different from all the rest, a distant external galaxy among a mass of stars. But if this insignificant external galaxy were a radio source why should not the

millions of other similar galaxies be sources also? This objection has been answered spectacularly by Baade and Minkowski at Mount Wilson and Palomar. The tiny galaxy, barely recognizable in photographs, is not similar to millions of other galaxies. It appears to consist of two galaxies in collision, a sufficiently remarkable object to warrant identification with the second most intense radio star in the sky. Subsequent more precise position measurements in Cambridge and Sydney have supported the identification which is now virtually clinched by the observations of angular size to be described shortly. "Radio stars" are associated with great catastrophies of the universe; super-nova, colliding galaxies. Further eventualities remain to be seen.

It is possible to derive information about the nature of the radio sources by an entirely independent method, a statistical analysis of their distribution. This method was first applied by the Cambridge workers who concluded that the angular distribution was not related to the structure of the galaxy. In Sydney, Mills[20] came to a different conclusion. He carried out a survey, the most comprehensive yet published, which led to the recognition of 77 sources (see figure 8). He found a concentration, which he considered significant, of the stronger sources towards the galactic plane. This is illustrated in figure 9 in which the numbers of sources of different intensity classes in five equal-area zones are depicted. Further, on examining the statistical distribution of intensity he found

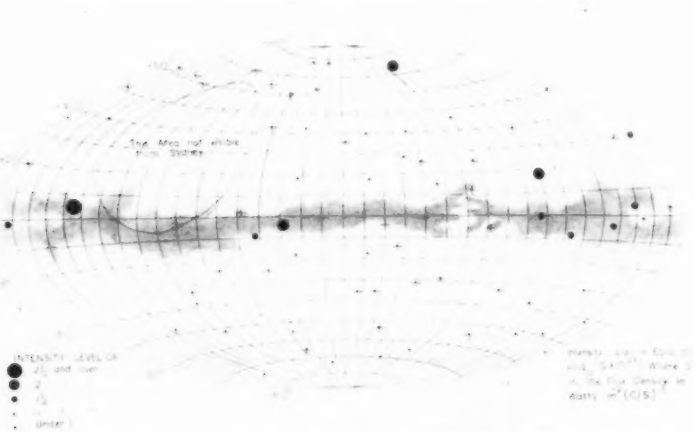

FIG. 8—The distribution of 77 discrete sources of cosmic radio waves over the sky according to Mills.[20]

that the former group, those near the galactic equator, showed a distribution consistent with their being concentrated in a thin disk. The remainder appeared to be distributed at random in space. These results are very different from those for optical stars where the bright ones, being

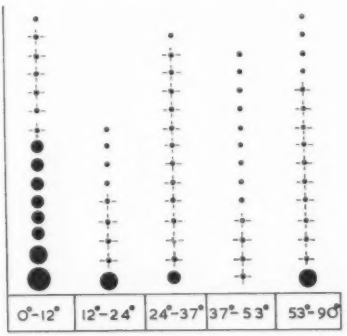

FIG. 9—Illustrating the galactic concentration of the stronger discrete sources. (Mills[20]).

relatively near, are distributed at random while the faint ones, which include many at distances comparable with galactic dimensions, show a galactic concentration. Mills concluded that the radio results indicated that there must be at least two classes of discrete sources. Class I included very intense sources distributed throughout the galaxy; Class II were either weaker ones at shorter distances, e.g. at distances like those of the brighter stars, or even more powerful ones outside the galactic system. These conclusions conform with the optical identifications which are now being made. A number of radio sources are now identified with peculiar nebulae within the galaxy, e.g. The Crab; others are identified with peculiar external galaxies, e.g. Cygnus. The evidence at present suggests that the Class II sources are extra-galactic.

Meanwhile the former mystery concerning the source of the fluctuations has been cleared up. These fluctuations were thought by the early observers to be due to variations in emission from the source itself. Such fluctuations would be expected to occur simultaneously at different places on the earth as, in fact, do solar bursts. This does not hold for the fluctuations from the radio stars.

This fact was discovered by Bolton in connection with simultaneous observations taken in 1948 in Sydney and New Zealand. He communicated this result privately to the English workers who followed it up very

effectively. They showed that the fluctuations originate in the terrestrial ionosphere. They are analogous to the optical twinkling of stars.

The most recent question to be settled concerns the angular size of the discrete sources. The early observations had given upper limits of a few minutes of arc and it seemed possible that the sources should be of stellar dimensions. However, in his survey of radio sources visible from Sydney, Mills[20] had found several with a minimum angular extent of half a degree. Later unpublished observations by Bolton showed the existence of many sources of several degrees extent. But the intense and well-known radio stars such as those in Cygnus remained unresolved until 1952 when workers in Cambridge, Manchester and Sydney almost simultaneously obtained finite results. The Cambridge group used the original two-aerial method; in Sydney Mills[21] employed an extension of this method utilizing a radio link to connect the two aerials so that the base line could be extended to 10 miles; and the Manchester workers employed a new and independent method. All workers agreed in finding sizes of the order of a minute or a few minutes of arc for some of the more intense sources. Beyond that the results are not directly comparable. The important conclusion is that the sizes are minutes of arc, definitely not those of single stars. Radio astronomy has thereby lost a graphic term; "radio star" must be replaced by "radio nebula".

The 1420 mc./sec. Atomic Hydrogen Line

The outstanding development in radio astronomy of the past few years was the discovery by Ewen and Purcell of Harvard that the galaxy emits the 1420 mc./sec. line of atomic hydrogen. Through the courtesy of Prof. Purcell the Radiophysics Laboratory was informed of this discovery at a very early stage and equipment was improvised to attempt to confirm it. This was successfully accomplished by Christiansen and Hindman as noted in a hasty postscript to the letter to *Nature* in which Ewen and Purcell announced their results.[22] The Australian equipment was then applied to give the first crude survey of the sky in the radiation of this line.[23] As was expected, the radiation showed a concentration towards the galactic equator.

The really interesting result, however, concerned the line profile and its variation in different directions. The natural width of the line is exceedingly narrow; observed frequency displacements, line widening and other more complex changes of profile are interpreted as being due to Doppler shifts. It was found that, over a whole quadrant of the Milky Way, the line was split into two distinct parts, as illustrated in figure 10(a), (full line), with a separation which varied in a continuous manner

as shown in figure 10(b). Now, objects in the galaxy rotate around the galactic centre in roughly circular orbits with velocities which vary with the distance from the centre. The resultant Doppler shift for an object in the galactic plane and in the general vicinity of the sun, is zero towards the centre and anti-centre and at right angles to these directions but reaches maxima in the intermediate 45° directions. Along the maxima, velocities increase with the distance of the object. The line profiles of figure 10 can be simply interpreted if the radiation originates in two vast elongated masses of hydrogen which lie at distances from the sun of

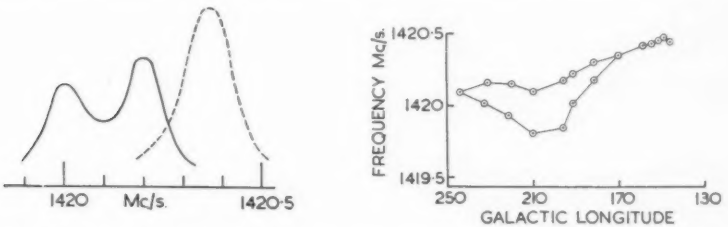

FIG. 10—Line profiles of the 1420 mc./sec. atomic hydrogen line from the galaxy. Left, two typical profiles, right, the centre frequency of each peak of the profile in a region around the galactic equator in which there are two main peaks. (Christiansen and Hindman[23]).

roughly 1000 and 4000 parsecs. These masses may well delineate spiral arms of the galaxy.

These results clearly called for more detailed and precise observations and the construction of more elaborate equipment was commenced. At the time of writing observations are about to recommence with the new equipment.

CONCLUSION

The cause of the development of some branch of science at a particular time and place is of interest to those concerned with the planning or the history of scientific research. Such developments do not follow a very obvious pattern. Radio astronomy, for example, has grown almost entirely outside astronomical observatories despite the fact that its objective is just that of conventional astronomy, the search for knowledge of the external universe.

The Australian development can be traced to the concentration on radar development during World War II. This brought together in a well-equipped laboratory a group of able young physicists with experience of radio techniques. At the conclusion of the war these men found

themselves without definite commitments and anxious to establish themselves in scientific research. In some countries this situation led to an exodus of the most able people from the government radar laboratories. In Australia the high scientific reputation of C.S.I.R.O., which had been built up under men like its original leader Sir David Rivett, prevented this trend. The men were actively encouraged by the executive to develop their science within the Organization.

It was in this environment that the first tentative observations in radio astronomy were undertaken. These observations were immediately successful and the Laboratory was encouraged to venture further into the field. Thus first-class men obtained access to first-class facilities and the subsequent developments in radio astronomy in Australia have followed from this beginning.

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THE RELATIVE ABUNDANCE OF HYDROGEN TO HELIUM IN STARS*

By Anne B. Underhill

Abstract

The determination of the relative abundance of hydrogen to helium in astronomical objects is reviewed and some recent results are collected. It is shown that both the study of the stellar interior and the study of stellar atmospheres suggest that the number of helium atoms in the stars is about four or five per cent. of the number of hydrogen atoms.

Since Eddington's early investigations of stellar structure in which he assumed that the stars were composed chiefly of metals like iron, it has become clear that the stars and the universe around us are composed chiefly of hydrogen. This hydrogen gas is not pure, however, but it is adulterated by a small amount of helium and by traces of all the other elements. The general question we wish to ask is what is the relative abundance of hydrogen to helium in astronomical objects. Answers to this question have been obtained from four different lines of study.

By further development of the methods initiated by Eddington, an estimate has been made of the relative abundance of hydrogen to helium in the inner core of a star where the energy is generated. This is done by computing a "model" star and by matching the observed luminosity to that computed from the known rate of conversion of hydrogen to helium by nuclear processes in the stellar interior. This method demands an adequate knowledge of stellar structure, as well as a quantitative knowledge of the nuclear processes involved. It has been applied in detail only to the sun, although attempts have been made to extend the method to certain stars.

Some recent results obtained by the general method of the last paragraph are summarised in Table I. The differences among these results are due to three main factors. First, our knowledge of the rates of the nuclear reactions involved has improved in recent years; secondly, it has become clear that the proton-proton reaction, which is equivalent to four hydrogen atoms combining directly in successive stages to form one helium atom, is the predominant source of stellar energy in solar-type stars; and thirdly, more is becoming known about the blocking power, or opacity, of stellar material at the high temperatures of stellar interiors. It is becoming increasingly clear that the manner in which energy works its way out from the centre of the star, where it is generated, depends very much

Contributions from the Dominion Astrophysical Observatory, No. 30.

TABLE I

THE RELATIVE ABUNDANCE OF HYDROGEN TO HELIUM FROM SOLAR MODELS

Author	Details of Method	H/He by Number
Epstein[1] 1951	carbon cycle and proton-proton reaction oxygen mixture	19.3
Keller[2] 1948	carbon cycle intermediate mixture	9.2
Schwarzschild[3] 1946	carbon cycle Russell mixture	4.6

upon the amount of carbon, oxygen, nitrogen, and neon present. Schwarzschild[3] assumed a small abundance of these elements, that given by the well-known "Russell mixture", while Keller[2] tried different amounts of oxygen and related elements. Epstein[1] also recognized the sensitivity of the opacity to the abundance of elements of the oxygen group, and in addition introduced the proton-proton nuclear reaction as an energy source supplementing the carbon cycle. In view of the uncertainties still existing in the theory of stellar interiors and of stellar energy production, it is premature to conclude that any of the results given in Table I is unequivocally correct. However it does seem that a relative abundance of helium to hydrogen atoms of about four or five per cent. (H/He = 20 to 25) would be consistent with the present studies of stellar structure and energy production.

A second method of estimating the hydrogen-helium ratio is from the relative intensities of the emission lines of hydrogen and helium in planetary nebulae. It may well be appreciated that to obtain significant results from such studies is difficult, for one must make assumptions about the relative volumes contributing to the various emission lines, and one also requires an adequate physical theory of the line-emission processes involved. Since some recent observations of planetary nebulae suggest that it is rather hazardous to assume that the emitting regions are homogeneous spheres, the estimates of the hydrogen-helium ratio found in this way should be considered as order-of-magnitude estimates only. Bowen and Wyse,[4] Aller and Menzel,[5] and Aller[6] have found H/He = 10 by number, while Menzel[7] in a review article proposes H/He = 5.

A third way of estimating the hydrogen-helium ratio is from a study of the intensities of the hydrogen and helium lines in stellar spectra. At present our theories of line formation are more satisfactory for absorption lines than for emission lines, so the most successful attempts to determine

the hydrogen-helium ratio are based upon the analysis of the strengths of absorption lines. The Balmer lines of hydrogen and the lines of helium which are observed in stellar spectra are subordinate lines arising from lower levels which are of the order of 10, 20, and 50 volts above the ground level for hydrogen, neutral helium, and ionized helium, respectively. Since in a stellar atmosphere the distribution of atoms among excited levels approximates a Boltzmann distribution, sufficient atoms for absorption lines to be formed are excited to these levels of high energy only if the temperature is high. Thus the hydrogen to helium ratio is best derived from a study of the relative intensities of the hydrogen and helium lines in the spectra of B- and O-type stars. These stars have surface temperatures from about 12,000°K. to 30,000° or 40,000°K. Certain hydrogen and helium lines are found in emission in the solar chromosphere and in solar prominences, and attempts have been made to estimate the relative abundance of hydrogen to helium from the strength of these lines. However, these methods are not very secure, because of the great uncertainties in the excitation processes and in the geometry involved.

Unsöld[8] in his detailed study of the B0 star τ Scorpii developed a method of estimating the number of hydrogen and helium atoms above the photosphere from the measured equivalent widths of the Balmer lines of hydrogen and of the lines of neutral helium. His method enables one to extrapolate from measured intensities of the absorption lines to obtain numbers of atoms. The atmosphere is treated as a thin layer at precisely one temperature and electron pressure, and it is assumed that this one thin layer is effectively the same for all lines. No explicit account is taken of the Stark effect of hydrogen or helium as lines shapes are not considered, but only the variation of the integrated or total absorption with increasing series number. In further studies of the spectrum of τ Scorpii, Unsöld[9] developed another method utilizing the Stark broadening of certain hydrogen and helium lines for determining the hydrogen-helium ratio.

The methods of Unsöld have been applied by Unsöld himself and by other workers to the available data on the intensities of the hydrogen and helium lines in B- and O-type spectra. The results of these analyses and of estimates of the hydrogen-helium ratio from solar emission lines are summarized in Table II. Also the results from the fourth method of estimating this ratio, the study of model atmosphere, is given in Table II.

The solar results for the hydrogen-helium ratio, which are reported by Minnaert[19] in a review article, are not directly comparable to the other results because they have been derived from the study of emission lines

of high excitation in the spectrum of an object of moderate temperature. The spectrophotometry of these lines yields an estimate of the number of recombination processes occurring per unit time in the place observed (solar chromosphere or prominence), but it is a difficult theoretical step to relate this datum uniquely to the total number of atoms of each element present. As in the case of the planetary nebulae, geometric considerations of the perhaps localized regions giving rise to the observed emission lines are vital. Also the question of departures from local thermodynamic equilibrium must be considered closely.

The results from the analyses of the absorption lines in B- and O-type stellar spectra show considerable diversity. However this spread is compatible with the accuracy of the methods. The results are only claimed to be accurate within a factor of two or three.

TABLE II

THE RELATIVE ABUNDANCE OF HYDROGEN TO HELIUM FROM STELLAR ATMOSPHERES

Author	Object Studied	Lines Used	H/He by Number
Menzel et al[19]	Solar Chromosphere	Emission Lines of	5.0
Unsöld[20]	Solar Prominence	H and HeI	5.0
Unsöld[8]	τ Scorpii	absorption lines of	5.7
Aller[10,11]	γ Pegasi	H and HeI	14.5
	ι Herculis		20.4
	δ Ceti		27.5
	10 Lacertae		11.9
Miczaika[12]	γ Pegasi		7.8
Becker[13]	ζ Ophiuchi		3.6
Voigt[14]	55 Cygni		4.1
Unsöld[15]	15 main sequence B stars		5.0
	3 supergiant B stars		3.2
Aller[16]	6 B-type stars		20.0
Miczaika[17]	18 O-type stars		3.9
Underhill[18]	O-type model atmosphere	absorption line of HeII	20–25

It is very difficult to assess the intrinsic value of these results. Apart from errors of measurement, which for the lines used should not be large if reasonable care was taken with the photometry, the greatest uncertainty concerns the effect of the approximations (1) that for the formation of any single absorption line of hydrogen or neutral helium in a B-type star, the atmosphere may be regarded as a thin layer at one pressure and temperature, and (2) that this *thin* layer is the *same* layer (i.e., has the same temperature and pressure) for all lines of a given spectral series and for *all* elements. Recently De Jager and Neven[21] have criticized the thin

layer concept used in the above connection, and have given an example, with reference to the solar case, to illustrate the fact which is evident from model-atmosphere computations that weak lines, particularly if they have a high excitation potential, are formed through a great depth of atmosphere. Model-atmosphere computations also indicate that any spectral line which is strongly broadened (by Stark effect in the cases in question) is formed over a wide range of depths of atmosphere. For instance, the core of the line may be formed in the outermost layers of the atmosphere while the wings are effectively formed at progressively deeper layers as one considers frequencies further from the line centre.

Neven[22] has carefully considered the approximate methods introduced by Unsöld, and has sought to improve these methods of analysis for the early-type stars. From a detailed study of high-dispersion spectra of the four B-type stars τ Scorpii, δ Ceti, γ Pegasi, and ι Herculis, he has estimated that the number of helium atoms relative to the number of hydrogen atoms is somewhat in excess of three per cent. Thus he obtains H/He = 30 approximately.

A fourth method of estimating the hydrogen-helium ratio is by means of model atmospheres. This method makes use of the consideration that if an adequate physical description of the dependence of the line absorption coefficient on pressure and temperature is available, the strength of any spectral line may be computed in detail as a function of the abundance of the carrier atom in the atmosphere. A plot of the computed equivalent width of the line against abundance defines a theoretical curve of growth for the line. Comparison with the observed strength of the line in a real stellar atmosphere corresponding in spectral type to the model gives an estimate of the abundance of the element. It is true that a model atmosphere gives an idealized representation of a real stellar atmosphere, but it seems reasonable to conclude that this representation is considerably more valid than that of a thin layer at one temperature and pressure. From this point of view the estimate of the hydrogen-helium content by model-atmosphere computations is to be preferred to that obtained by the methods of Unsöld.

The model atmosphere, for which the computations reported in Table II were made, corresponds to a stellar excitation temperature of about 30,000°K. or spectral type about O9.5 V. The results indicate that hydrogen is more abundant by number than helium by a factor of 20 to 25. This result is about the same as that derived by Epstein[1] from consideration of the internal structure of the sun, and that proposed by Neven.[22] The greatest uncertainty in the method lies in how well the model atmosphere represents a real stellar atmosphere, and in particular the real

stellar atmosphere with which it is compared. The model has been tested by computing the strengths of other spectral features and comparing them with observed features. The results of this test have been quite satisfactory.

The strength of a line of ionized helium was predicted, because for ionized helium a representation of the line absorption coefficient broadened by Stark effect could be obtained since ionized helium is hydrogen-like. At present this method cannot be used to compute the strengths of the neutral helium lines, for an adequate theory of the broadening of the neutral helium lines in stellar spectra does not exist. The neutral helium problem is difficult because one can show by consideration of the energies, inter-particle distances, etc., involved that the "adiabatic hypothesis" will break down, as is evidenced by the appearance of forbidden lines, and one can also show that the "sudden hypothesis" will not suffice. It would be of importance to obtain an adequate representation of the line absorption coefficient for the lines of neutral helium broadened by the interatomic Stark effect of stellar atmospheres in order to compute the strengths of these lines in B-type model atmospheres. Then a further estimate of the hydrogen to helium ratio could be made. The neutral helium lines are, apart from the hydrogen lines, the strongest features in B-type spectra, and it is unfortunate that they cannot be used at present to obtain an estimate of the temperature and electron pressure in these atmospheres. The problem is more or less intractable, being a four-body problem in quantum mechanics with time-dependence.

A review of the material presented here suggests that the number of helium atoms in stellar atmospheres is about four or five per cent. of the number of hydrogen atoms. It is not clear to what extent the results from the study of stellar atmospheres can be related to those from the study of the stellar interior. This relationship depends upon how much mixing there is throughout the star.

There is some indication that all stars do not have the same hydrogen and helium content. Bidelman[23] has recently described an O-type star, H.D. 160641, in which the hydrogen lines are weak or absent while the helium and carbon lines are very strong. A few years ago Popper[24] drew attention to the B-type star H.D. 124448 in which the same thing was true, and Thackeray[25] has found more of these stars in the southern hemisphere. There are also a few stars of later spectral type such as υ Sagittarii, H.D. 30353, and R Coronae Borealis, which do not seem to have the usual amount of hydrogen and helium in their atmospheres. These peculiar stars are few in number, and their spectral oddities do not seem to be explicable entirely in terms of peculiar excitation condi-

tions. Rather they suggest that the broad assumption, that the chemical composition of all the stars is the same, is not an absolute law—some exceptions do occur.

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Dominion Astrophysical Observatory,
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ON THE IDENTIFICATION OF TERRESTRIAL METEORITE CRATERS*

By Paul W. Healy, Lincoln LaPaz, and Frederick C. Leonard

Recently a considerable number of crater-like topographic features have been asserted, more or less positively, to be due to meteoritic impact. Critical examination of the bases for such identifications in the case of the most widely publicized features of this sort discloses no valid reason for accepting the meteoritic nature of the craters in question. The most flagrant case is that of Chubb Crater in Canada, where (in the complete absence of meteorites and also of materials definitely identifiable as produced by the heat and pressure incident to meteoritic impact) the asserted occurrence of a magnetic anomaly, in rock admittedly rich in segregations of magnetite and allied minerals, is advanced as "proof" that the feature is a meteorite crater.

A meteoritic origin has been suggested also for Crater Eleganté in the famous Pinacate volcanic region of Sonora, Mexico, although several positive identifications of this feature as a *caldera* were made and published by geologists in the interval 1912–1952. Additional examples of similar misidentifications as meteorite craters of terrestrial craters clearly of non-meteoritic origin can be cited: for example, Lake Bosumtwi, in Ashanti, Africa; the Le Clot Crater in France, the volcanic crater of Malha in northern Africa, and others.

The purpose of the present note is to point out that the authentication of every meteorite crater in the list of these features at present recognized as such by meteoriticists rests on satisfaction of one or both of the following indentification criteria:

1. Actual discovery in or near the crater of meteorites or of metamorphosed or altered materials definitely known to have resulted from meteoritic impact (e.g., silica glass lechatelierite, or oxidite.)
2. Actual observation of meteorite falls having impact points in the crater areas, as in the cases of the crater fields of the famous Podkamennaya Tunguska fall and the very recent Ussuri (Sikhota Alin) fall in the Maritime District of Eastern Siberia.

In addition to the forenamed principal criteria, there are auxiliary criteria—often of a quite compelling nature—as, for example, the upturning and even overthrow of strata horizontally bedded and the clear evidence of bilateral symmetry, as at the greatest of all recognized

*Reprinted from mimeographed abstract.

meteorite craters, the Barringer Meteorite Crater near Canyon Diablo, Arizona.

In the case of Chubb Crater, of Crater Eleganté, and of other craters recently asserted to be of meteoritic origin, neither of the two principal criteria nor any of the various auxiliary criteria are satisfied; for example, at Chubb Crater there is no evidence of bilateral symmetry and no uptilting evident in the inner walls of the crater; in fact, the curvatures of the inner and outer halves of the rim are almost identical—quite unlike those at Barringer Crater and other authenticated meteorite craters.

Under these circumstances, to claim that a "proof" of the meteoritic nature of a crater can be given merely on the basis of the existence of magnetic anomalies—i.e., magnetic highs, which are known to occur in and near many terrestrial features of obviously non-meteoritic origin—is, scientifically, quite unjustifiable.

The criticisms of current practices relative to the identification of terrestrial craters as meteoritic presented in this note apply with even greater force to the wholesale identification as meteorite craters of crater-like features on such an inaccessible body as our satellite.

Institute of Meteoritics, University of New Mexico, Albuquerque.

METEOR NEWS

By Peter M. Millman, *Dominion Observatory, Ottawa*

Notes on Canadian Meteorites

Since publishing a provisional catalogue of the Canadian meteorites in the January-February issue of the Journal for this year I have received a number of helpful corrections and additions, in particular detailed notes from Dr. E. P. Henderson at the United States National Museum in Washington and Dr. Lincoln LaPaz at the Institute of Meteoritics in Albuquerque, New Mexico. I should like to thank these correspondents for their assistance.

As a result of this new information an appendix to the catalogue has been compiled. This contains an additional meteorite not listed before. In the original catalogue Skookum and Gay Gulch were listed separately, not so much to throw doubt on the rather high probability of their belonging to the same fall, but in the hopes of eventually getting away from the name "Klondike", for which I can find no Canadian authorization. Reference to the map in the original publication indicates that Klondike is not a particularly suitable name, being too general. If a single name is desired, Eldorado Creek would be much better.

Among our Canadian meteorites Iron Creek probably has the most interesting history. It was brought east from what is now Alberta by Captain Butler in 1871. The following note on this meteorite is quoted from Flight[13]:

> Longer than any man could say, it had lain on the summit of a hill out on the southern prairies. It had been a medicine-stone of surpassing virtue among the Indians far and wide, and no tribe, or member of a tribe, would pass in the neighbourhood without visiting this great medicine. It was said to be increasing yearly in weight. Old men remember to have heard old men say that they had, at one time, lifted it easily from the ground; now, no single man can carry it. Not very long before Captain Butler saw this meteorite, it had been removed from the hill on which it had so long rested and been brought to Victoria. When the Indians found that it had been taken away, they were loud in the expression of their regret. The old medicine-men declared that its removal would bring great misfortune, and that war, disease, and dearth of buffalo would afflict the tribes of the Saskatchewan. . . . Never, probably, since the first trader had traversed their land had so many afflictions of war, famine, and plague fallen upon the Crees and the Blackfeet as during the year succeeding the removal of their Manito-stone from the lone hill-top upon which the skies had cast it.

IRON CREEK was presented to Victoria University, Toronto, and for many years has been on display there.

By way of contrast, the record of finding HOLMAN ISLAND is given below. This short note by Canon J. H. Webster appeared in *The News of the North*[33], a 6-page newspaper published in Yellowknife, N.W.T.

> An Eskimo named Niakoaluk recently found a strange piece of black substance which he took to Holman Island post. It was a meteorite which must have fallen quite recently (about the end of February or the beginning of March) for it was found on the sea ice which formed about that time. It is not a very large piece but is interesting to examine.

Approximately half of the original stone has been acquired by the Geological Survey of Canada. It may be remarked that, though this cannot be listed as a witnessed fall, the date of find determines the time of fall to within a month or two.

By an interesting coincidence the latest Canadian meteorite, ABEE, fell just 8 miles south of the Newbrook Meteor Observatory in Alberta. It is hoped to publish a full account of this fall in the near future. The scientific literature on Canadian meteorites is not very extensive. In the accompanying bibliography all descriptive papers have been listed, but meteorite catalogues have not, in general, been included.

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Appendix to a Catalogue of Canadian Meteorites

Meteorite No.	*Delete*	*Add*
1.		(MPG) 301 (Tu) 170 (Pr) 8
2.		(W) 131
3.	*/21–1700*	*/21–1900*
4.		(W) 382 (Pr) 24
5.	*Fi 1888/–/–* (W) 75	*Fi 1888/4/30* (W) 82 (Pr) 136
6.		(Pr) 139
8.	(?) main mass	(G) main mass
9.	(W) 578	(W) 557 (Pr) 32
10.		(W) 168

11.		(W)	129
		(L)	114
12.		(W)	82
13.		(L)	360
17.		(W)	1733
		(UNM)	238
18.		chondrite	
19.	*Fi 1939/–/–*	*Fi 1938/–/–*	
	53° 33′ N 113° 30′ W	53° 40′ N 113° 25′ W	
		(H) hexahedrite	
21.		(W)	205

Dr. Lincoln LaPaz, Director of the Institute of Meteoritics, University of New Mexico, supplies the following information concerning a Canadian meteorite he recovered some years ago:

20a. *Fi 1944/–/–* BELLY RIVER
17.4 lb (7.900 gm.) 49° 30′ N.* 133° W.*
Stone (Ca) veined chondrite
(UNM) main mass

ABBREVIATIONS

(Pr)	Landesmuseum, Praha.
(Tu)	Tübingen University.
(UNM)	University of New Mexico.
(MPG)	Museum of Practical Geology, London.

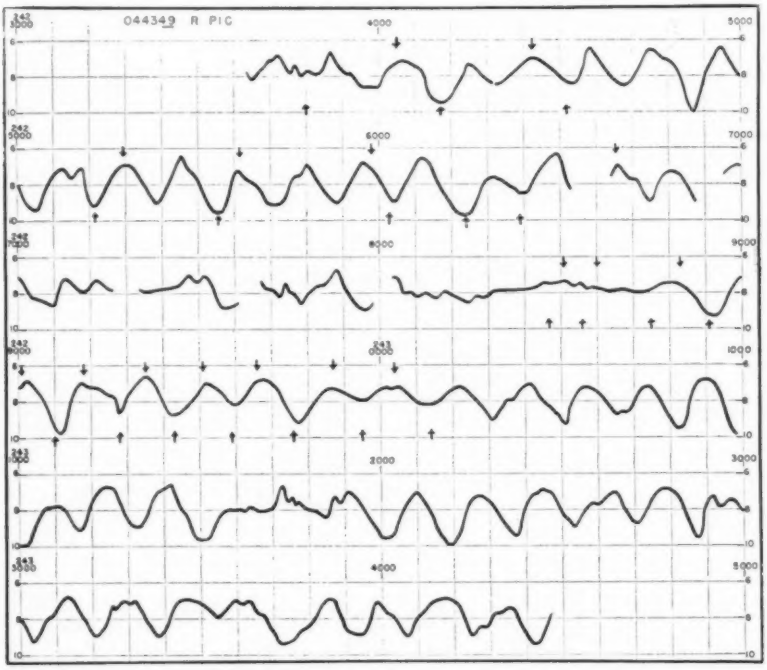
VARIABLE STAR NOTES

American Association of Variable Star Observers

By MARGARET W. MAYALL, *Recorder*

DURING the year 1952–1953, a special study has been made of a group of bright, red, semi-regular variables. A grant from the U. S. Office of Naval Research has made it possible to employ a part-time assistant to search the original records in the A.A.V.S.O. files for all the unpublished observations of these interesting and peculiar stars. It has proved to be a worthwhile project. Preliminary reports have been given at recent meetings of the A.A.V.S.O., and some of the light curves were exhibited.

R Pictoris 044349. One of the variables studied under the Office of Naval Research project is R Pictoris. A thorough study of photographic and visual observations from 1893 to 1932 (J. D. 2412465-2426805) was made by Father O'Connell (*Harv.*



Bulletin 892, p. 9, 1933). He noted an indication of an increase in the period from 163 days before 1913, to 167 days between 1913 and 1922, and to about 172 days between 1922 and 1932. S. Gaposchkin, in his work for the Milton Bureau study of bright variables (*Harv. Annals*, vol. 115, p. 108), extended the photographic observations of R Pictoris from 1936 to 1941 (J. D. 2428000 to 2430000). The light curve in figure 1 is plotted from the 10-day means of A.A.V.S.O. visual observations from 1923 to 1953. The period from 1932 through 1937 is shown as a critical phase in

TABLE 1

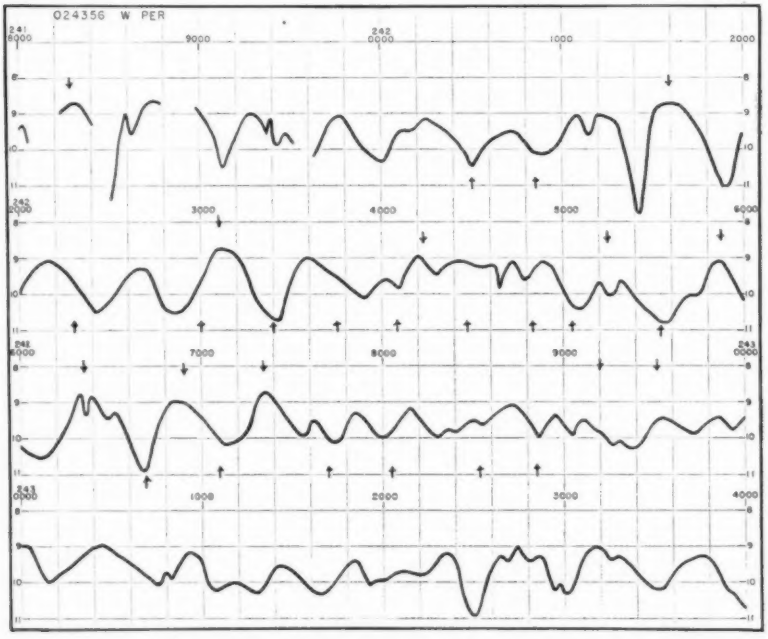
R Pictoris

Maxima			Minima		
J.D.	Mag.	Phase	J.D.	Mag.	Phase
26805	7.3	155.843	26745	8.9	155.494
26980	7.1	156.860	27075	8.6	157.413
27130	7.3	157.732	27180	7.9	158.023
27220	7.4	158.256	27360	8.1	159.070
27480	7.1	159.768	27590	8.8	160.407
27680 :	7.6	160.930	27775	8.3	161.482
27880	6.7	162.093	27950	8.8	162.500
28030 :	7.2	162.965	28250	8.5	164.244
28520 :	7.3	165.814	28700	7.9	166.860
28810	7.4	167.500	28925	9.2	168.169
29015	6.9	168.692	29110	9.7	169.244
29185	6.9	169.680	29280	8.3	170.232
29350	6.7	170.639	29435	8.7	171.134
29520	7.0	171.628	29605	8.2	172.122
29675	6.9	172.529	29775	9.1	173.110
29865	7.3	173.634	29950	7.8	174.128
30030	7.2	174.593	30125	8.2	175.145
30215	7.2	175.668	30310	9.0	176.221
30410	7.1	176.802	30510	9.3	177.384
30570	7.3	177.732	30675	8.6	178.343
30735	7.2	178.692	30830	9.5	179.244
30910	6.9	179.709	31000	9.9	180.232
31090	7.8	180.756	31165	9.0	181.192
31240	6.8	181.628	31320	8.9	182.092
31405	6.8	182.587	31505	9.7	183.168
31600 :	8.0	183.721	31680	8.2	184.186
31725	6.8	184.448	31830	8.4	185.058
31905	7.0	185.494	32010	9.5	186.105
32095	7.0	186.599	32180	10.0	187.093
32270	7.2	187.616	32365	9.4	188.168
32440	6.9	188.605	32530	9.0	189.128
32640	7.1	189.767	32705	8.7	190.145
32780	6.8	190.581	32870	9.4	191.105
32950	7.4	191.570	33035	9.3	192.064
33130	6.8	192.616	33210	9.0	193.081
33290	7.1	193.546	33380	9.0	194.070
33455	7.0	194.506	33540	8.0	195.000
33630	7.0	195.523	33735	9.3	196.134
33840	7.0	196.744	33930	8.8	197.267
33985	7.1	197.587	34070	9.0	198.081
34160	6.9	198.605	34260	8.9	199.186
34335	7.5	199.622	34425	9.5	200.145

the history of R Pictoris, when the amplitude of variation decreased until it became almost constant for about 800 days. Then the star returned to its normal, semi-regular type of variation, with an amplitude of about two magnitudes and an indication of a period of about 172 days. The arrows pointing toward the curves in figure 1 indicate times of photographic maxima and minima, as determined by O'Connell (before J. D. 2428000) and Gaposchkin (after J. D. 2428000).

Table I lists the visual maxima and minima of R Pictoris, a continuation of the tables given by O'Connell and Gaposchkin (*op. cit.*). The phase is computed from a period of 172 days, which fits these observations better than the 167.5 days used for the earlier observations. Some unpublished work by Leon Campbell, on variables with changing periods, shows that he considered that in 1922 the mean period of R Pictoris had changed from 165 days to 171 days.

W Persei 024356. Another of the semi-regular red variables of the O.N.R. Project is W Persei. It has a large variation in amplitude, as well as in the length of intervals between maxima. Figure 2 shows the 10-day mean visual light curve of W Persei,



with the arrows indicating times of maxima and minima determined photographically by C. P. Gaposchkin (*Harv. Annals,* vol. 118, p. 199). A median period of 469 days gives the best correlation for the times of greatest regularity, when the variable has a large amplitude. The star returned to phase again after its recovery from the disturbances which occurred around J. D. 2424000 and 2427600. The median cycle

of 380 days determined by Dr. Gaposchkin is not borne out by the visual observations. Table II lists the times of maxima and minima of W Persei, with the visual magnitudes for the 44 years of almost continuous observations.

TABLE II

W Persei—Maxima

J.D.	Mag.	J.D.	Mag.	J.D.	Mag.	J.D.	Mag.
18310	8.7	23120	8.8	26860	9.0	30020	9.0
18740	8.7	23580	9.0	27350	8.7	30440	9.0
19280	9.0	24020 :	9.6	27620	9.5	30930	9.2
19770	9.1	24200 :	9.0	27850	9.3	31180	10.0
20250	9.2	24440 :	9.1	28150	9.2	31430	9.6
20720	9.5	24720 :	9.1	28720	9.1	31840	9.4
21150	9.0	24870 :	9.1	28950	9.4	32350	9.2
21590	8.7	25280 :	9.6	29110	9.6	32740	9.0
22160	9.1	25860	9.1	29540	9.4	33170	9.0
22670	9.3	26370	8.9	29860	9.4	33760	9.3

W Persei—Minima

J.D.	Mag.	J.D.	Mag.	J.D.	Mag.	J.D.	Mag.
18500 :	11.5 :	23430	10.7	27150	10.2	30150	10.0
19130	10.5	23900	10.1	27560	9.9	30750	10.1
19600 :	10.2 :	24100	9.8	27740	10.1	31070	10.2
20010	10.4	24300	9.4	28000	10.0	31300	10.3
20500	10.5	24650	9.8	28300	9.9	31650	10.3
20900	10.1	24790	9.6	28860	10.0	31920 :	10.1
21430	11.8	25100	10.4	29050	9.9	32500	10.9
21900	11.0	25560	10.8	29380	10.3	33010	10.3
22420	10.5	26110	10.5	29720	9.9	33520	10.2
22860	10.5	26660	10.9	29930	9.7	34000	10.7

Nova Search. Nova Search reports were received from eight persons in April and six persons in May. In the following table we list for each observer: month of observation; areas observed (in italics); number of nights region was checked; and the limiting magnitude.

Bluncк, Victor, Apr.–*8, 9, 10*: 3, 6; May–*8, 9, 10*: 1, 6.

Darsenius, Gunnar, Apr.–*Dome*: 6, 2; *16, 17*: 6, 6; May–*Dome*: 2, 2; *16, 17*: 4, 6.

*Diedrich, DeLorne, Apr.–*Dome*: 1, 2; *94*: 1, 6; May–*Dome*: 1, 2; *40, 94*: 1, 6.

*Diedrich, George, Apr.–*Dome*: 2, 2; *56*: 2, 6; May–*Dome*: 5, 2; *56*: 3, 6; *56*: 1, 5; *78*: 2, 6.

*Maher, James, Apr.–*Dome*: 2, 2; *50*: 3, 4; *50*: 1, 3; *59*: 1, 4.

*Rick, Louis, Apr.–*Dome*: 3, 2; *Dome*: 2, 1; *18*: 4, 4; *65*: 3, 4; May–*Dome*: 3, 2.

Rosebrugh, David, Apr.–*Dome*: 4, 3; *Dome*: 1, 2; *1*: 1, 4; *1*:1, 3; *34*: 3, 4. May–*Dome*: 3, 3; *Dome*: 1, 2; *1*: 1, 3; *34*: 2, 4.

Smith, Franklin W., Apr.–*3, 4*: 7, 6; May–*3, 4*: 1, 6.

*Black River Astronomical Society

Observations received during April and May 1953: During April, 57 observers contributed 4,264 observations, and in May 3,703 observations were received from 52 observers—a total of 7,967 for the two months.

Observer	April		May		Observer	April		May	
	No. Var.	No. Ests.	No. Var.	No. Ests.		No. Var.	No. Ests.	No. Var.	No. Ests.
Adams, Robert M.	63	152	56	170	Isaak, George	...	...	12	39
Ahnert, Paul	24	171	...	...	Jahn, Artur	...	...	5	24
Ancarani, Mario	21	50	...	...	Johnsson, Robert G.	...	...	5	5
Anderer, Joseph A.	22	30	10	13	Kelley, Leo A.	9	19	3	3
Anderson, Curtis E.	59	116	81	102	Kelly, Frank J.	...	...	11	14
Archer, S.	9	22	...	...	de Kock, Reginald	126	567	126	672
Beidler, Herbert B.	10	21	18	44	Kuenzi, Edward W.	5	7	6	27
Blunck, Victor H.	2	2	8	10	Lowder, Wayne M.	9	9	...	...
Botham, John H.	14	21	18	23	Mebius, William G.	3	5	4	6
Boutell, Hugh G.	5	34	6	26	Meek, Joseph W.	31	197	...	...
Buckstaff, Ralph N.	14	20	22	45	Miller, William A.	26	30	20	25
Chandra, Radha G.	44	54	60	83	Montague, Allen C.	18	25	22	42
Charles, Donald F.	26	26	40	50	Oravec, Edward G.	104	365	84	265
Chester, Bryant	7	7	...	...	Orttung, W.	2	2	...	...
Chiabotta, Ronald	...	...	1	1	O'Sullivan, William	14	39	9	15
Churms, J.	...	...	13	30	Overbeek, M. D.	68	128	81	159
Cobb, Hensley	7	11	5	9	Parker, P. O	31	33	49	51
Cragg, Thomas A.	140	141	163	163	Parks, J. E.	...	...	1	1
Dafter, Rosina	8	49	...	...	Pearcy, Robert E.	7	7	...	...
Darsenius, G. O.	84	224	50	145	Peltier, Leslie C.	48	139	31	100
Diedrich, DeLorne	1	1	5	7	Pohl, Eckhard	16	104	15	41
Diedrich, George	3	5	6	10	Renner, Carl J.	112	112	68	68
Elias, Demetrius P.	73	319	85	458	Rick, Louis	1	2	...	...
Estremadoyro, G.A.	...	...	2	2	Rizzo, P. V.	...	...	8	41
Estremadoyro, V.A.	3	3	9	9	Rosebrugh, D. W.	17	77	15	58
Fernald, Cyrus F.	145	197	139	225	Smits, P.	...	...	13	34
Ficonetti, Rene	23	34	...	...	Taboada, Domingo	97	143	31	31
Ford, Clinton B.	126	126	62	62	Tarbell, E. D.	7	10	...	...
Galbraith, William	48	102	20	24	Thomas, M. A.	...	...	4	5
Gaustad, John	5	5	8	10	Venter, S. C.	26	39	44	74
Harrison, C.	4	4	...	...	Welker, Frank	...	...	7	7
Hartmann, F.	136	144	128	139	Wyckoff, Jerome	22	33	20	20
Hiett, Lancaster	9	16	7	16	Zahner, Donald D.	41	49	...	...
Holloway, Leith	6	9	...	...	Zimmerman, Sidney	2	2	...	...
Howell, Shapleigh	5	5	...	...					

The Annual Meeting of the A.A.V.S.O. will be held at the Harvard College Observatory on Friday and Saturday, October 9 and 10, 1953. We hope many of the members will stay in Cambridge over the weekend to attend the Convention of Amateur Instrument Makers on Sunday and Monday.

Harvard College Observatory
Cambridge 38, Massachusetts
June 15, 1953

REVIEW OF PUBLICATIONS

A Guide to the Moon by Patrick Moore. Pages 256; 6¾ x 9¼ in. New York, W. W. Norton and Company, Inc., 1953. Price $3.95.

The moon is our closest astronomical neighbour and, as such, is a fascinating object for study with small telescopes. The writer of this book is an active observer in the Lunar Section of the British Astronomical Association, and is well qualified to discuss his subject. The book is written in a lively manner, and covers the theories of the origin of the moon, its present condition and speculation about man's colonization of the moon.

Readers of this JOURNAL who delve into *A Guide to the Moon* will be pleased that in his historical sketch of observers of the moon, the author gives Sir William Lower his place with Galileo as an early telescope observer (p. 52). As has been pointed out in *Out of Old Books* (vol. 47, p. 15, 1953) the early English astronomers have not received adequate recognition of their work. Also the discussion of the blue moon (p. 166) will bring to mind other JOURNAL articles on this subject (vol. 40, p. 164, 1946; vol. 44, p. 241, 1950).

According to the author careful observation shows that the moon is not changeless. Misty dawn effects have been observed in some craters. From this and from theoretical considerations the author concludes that the moon may have a very tenuous atmosphere, 1/10,000 that of the earth's atmosphere. He points out that this is not adequate for breathing, but it would be a shield from meteors. No positive instances of lunar meteors have yet been found, but lunar observers in Britain, Europe, America and Japan are co-operating in this search.

Changes in colour and brilliancy of some regions are said to have been observed. Two cases of changing form of craters are cited, and it is suggested that these areas are well worth watching.

Appendices include instructions for observing the moon; lists of lunar literature and maps; a table of forthcoming lunar eclipses stating if these are visible in England or United States; description of the features on the surface of the moon, according to quadrants.

Many authorities will not agree with the author when he states "there are certainly many other solar systems, comparable to ours, among the

countless stars of the galaxies" (p. 31); "for an eclipse to take place, full moon must occur exactly at a node" (p. 156); "we know that vegetation is abundant on Mars" (p. 179). Also this reviewer is not convinced of the need or advisability of speculation concerning space travel and the formation of a lunar base. However, this subject is confined, for the most part, to two chapters, and does not materially detract from the enjoyment of the book. *A Guide to the Moon* is an immensely fascinating book, leaving the reader anxious for a clear night with good seeing in order to become better acquainted with details on the moon, or to trace rays which radiate from a crater on the back of the moon, or to look for mists around Plato, or to watch Messier for changes.

R. J. N.

Comets and Meteor Streams by J. G. Porter. Pages ix plus 123; 6¼ x 10 in. London, Chapman and Hall, 1952. Price 28*s* ($5.50 in Canada).

This is the second volume in the International Astrophysics Series. The announced aim of this series is to provide authoritative works suitable for both specialists and students. The book under review covers a fairly restricted field and deals chiefly with the dynamics of comets and meteors, and the computation of the orbits of these bodies.

In spite of the restricted field it is difficult in a book of this size to give adequate coverage to both the above phases of the subject. Most of the equations used in orbit work are mentioned but the treatment is not complete enough to serve as a general guide to computing. On the other hand the general interest of the book would have been increased if some of the problems in dynamics had been treated more fully and if the nature of meteors and meteor showers had been briefly summarized in a few descriptive paragraphs.

Apart from this lack of completeness the book is clearly written and is full of thought provoking information. Not the least valuable feature is a list of bibliographical references at the end of each chapter. These make it possible to follow up in more detail any desired topic. Six fine plates of comets are included but illustrations of meteors are restricted to two rather unimpressive trails which happened to appear on comet photographs.

This volume can be heartily recommended to any student seriously interested in the dynamics of the solar system. It provides a very convenient summary of reference material for the astronomer and will give anyone a new insight into the motions of the smallest members of our sun's family.

P. M. M.

NOTES AND QUERIES

The National Maritime Museum, Greenwich

One of the oldest, active observatories in the world is now joining the ranks of the "has beens". However, even though all the instruments in present use at the Greenwich Observatory are being moved to Herstmonceux, the old building will not stand idle. It is being converted into the National Maritime Museum and therefore many of the older retired instruments will remain as they are.

The Greenwich Observatory was founded in 1675 by Charles II. The Rev. John Flamsteed was appointed "to apply himself" as the king's astronomer, "with the most exact care and diligence to the Rectifying the Tables of the Motions of the Heavens and the Places of the Fixed Stars, in order to find out the so much desired Longitude at Sea, for the perfecting of the Art of Navigation". Through the centuries since 1675 this has been the main purpose of the work at Greenwich. Some of the reminders of this past which the visitors will be able to inspect are Halley's transit instrument (the first in England), Bradley's zenith sector, used by him in the discovery of aberration of light and the nutation of the earth's axis, Airy's transit circle (dated 1851), and the instrument that defines the position of zero longitude.

An interesting custom that dates back to 1833 will be resumed. This is the dropping of the Time-Ball at 1.00 p.m. In the olden days the captains of the ships in the docks checked their chronometers at that time. The Time-Ball was dropped directly by the mean solar clock that regulated the rest of the country's time.

B. R. C.

The Temperature of Mars

The mean range of temperature on Mars has been found by Frank A. Gifford to be between $-50°$F. and $+70°$F. The measurement of the energy radiated by Mars was started in 1924 by Coblentz and Lampland. Gifford, who is with the United States Weather Bureau, did the present work at Lowell for the Planetary Atmosphere Project under a contract from the Air Force (*Science News Letter,* vol. 65, p. 238, 1953). For the first time evidence was found that the annual mean temperature of the surface of Mars lags behind the movement of the sun. A daily lag was

also found, confirming previous determinations; the hottest time of day on Mars is about an hour and a half after the sun is overhead. These lags are further evidence that Mars has an atmosphere.

R. J. N.

THE SCALE OF THE UNIVERSE

The size of the universe has been doubled recently as a result of Dr. Walter Baade's investigation on the Andromeda nebula, M 31. (*A.S.P. Leaflet*, No. 290). This extra-galactic nebula just visible to the naked eye, has been used for estimating the distances of other nebulae. M 31 is relatively close to us and it can be resolved into individual stars in the large telescopes. Among the observed stars the δ Cephei-type variables are of great importance, because they have been used as distance indicators. There is a well-established relation between the luminosity of the Cepheid-variables and the period of their change in brightness (about ten days). Once we know the distance of a single Cepheid, the relation can be calibrated in absolute magnitudes. It is then a matter of simple calculation to find the distance of the Cepheid-variable and subsequently of the nebula in which the star is situated. The calibration of the absolute magnitude scale—the so called zero-point—of the period-luminosity relation has been obtained through a study of the motion of Cepheids in the vicinity of sun and through studies of variables in globular clusters. One assumption has to be made: that the Cepheids in globular clusters and in galaxies are similar in their nature. This assumption however has been shown to be incorrect.

In 1944 Dr. Baade of Mount Wilson discovered two distinct groups among the stars. They have been referred to as population I and II. The most striking difference between the two populations is that the brightest members of population I are one hundred times more luminous than those of population II. Cepheids of both populations fit the period-luminosity relation, but the zero-point of the magnitude scale is shifted by one and a half magnitudes relative to the other. This was discovered from differences in the shape of the light curves. The most important fact is, that Cepheids in M 31 belong to population I, while those of globular clusters to population II. The first determination of the distance of M 31 was based on the period-luminosity relation of Cepheids of population II; the new distance of this nebula has to be corrected by one and a half magnitudes. This places M 31 in a distance of one and a half million light-years, twice as far as before.

It has been mentioned that M 31 is a "yardstick" by which the distances of other extra-galactic nebulae are measured. A doubling of the

"yardstick" would consequently mean a doubling of the size of observable universe. The limit of the 200-inch telescope has thus been pushed to about two thousand million light-years.

The change in the size of the universe has its cosmological consequences. The rate of expansion of the universe (Hubble-effect) is just one half of the old value and comes much closer to the theoretical requirements of Einstein's cosmology. Furthermore, the age of the universe, which is related to the Hubble-effect, gives us a value of 4 thousand million years. It should be mentioned that the age of the earth is estimated to be between 2 and 3.5 thousand million years. Does it imply the possibility that universe and earth were born at the same time?

G. A. B.

Radio Astronomy and Galactic Structure

The 21 cm. hydrogen emission line, discovered by Ewen and Purcell in 1951, has given valuable information about the structure of our galaxy. This radiation is caused by a transition of very low probability between two hyperfine-structure sub-levels in the ground state of the hydrogen atom. However, the amount of hydrogen in the galaxy is so great that the radiation may be detected. The detection is also made easier by the fact that inter-stellar material is transparent for this radiation. Hence it may be used to study the distribution of neutral hydrogen throughout the galaxy. Oort has used the observations to trace two definite spiral arms and to show that interstellar hydrogen is concentrated in these arms.

Another interesting observation is that the line, which normally has a width of about 140 kc./sec., splits into two lines in the direction where Doppler shifts from galactic rotation are expected. If the split is a result of galactic rotation, it is possible to find the position of the sources of the two line-components. The sources appear large elongated masses of hydrogen forming arcs, which suggests spiral structure. These arcs are at distances of about one to four kiloparsecs from the sun. This hypothesis has been put forth as additional confirmation of the spiral structure of our galaxy by Christiansen and Hindman of the Radiophysics Division of the Commonwealth Scientific and Industrial Organization in Australia.

Results are being reported constantly in this branch of astronomy, and each result is another piece in the puzzle of our galactic structure.

B. R. C.

The Centenary of Christian Johann Doppler (1803–1853)

A hundred years ago on March 17 Doppler died in Venice at the age of fifty. He published a number of papers on analytical geometry, optics and the wave theory of light. The paper of most importance to astronomy

was printed in 1842. In this he explained a theory which after development became known as the "Doppler Principle" of the shift in wavelength of radiation from a source in motion.

Doppler's original ideas were incorrect; he thought the velocity of stars could be determined by their colour, those approaching rapidly should appear blue and those receding rapidly should appear red, the others white. The effect for sound from a moving source was verified experimentally by Buys-Ballot in 1845. It was not until 1849 that Fizeau developed the correct explanation of the application of the principle to light, showing how it could be used to measure the relative velocities in the line of sight. Sir William Huggins in 1868 was the first to measure the radial velocities of some of the brighter stars.

C. A. C.

Bruce Gold Medal Awarded to Harold D. Babcock

The Astronomical Society of the Pacific has announced that the Bruce Gold Medal for this year has been awarded to Harold Delos Babcock, astronomer emeritus of the Mount Wilson Observatory. This medal is awarded for outstanding achievement in some field of astronomy.

Harold D. Babcock was born in a small town in Wisconsin, but has spent most of his life in California. He attended the University of California and after a short session at the National Bureau of Standards, he was appointed as physicist to the Mount Wilson Solar Observatory in 1909. Here he has done fundamental work in the determination of precise wave-lengths in laboratory spectra, in the measurement of the general magnetic field of the sun and developed the technique of making large gratings of high precision. Canadians will be interested to know that Babcock accurately measured the wave-length of the auroral green line at 5577A. The University of Toronto physicists, McLennan and Shrum, studying the wave-lengths of oxygen, were led to the identification of the auroral line as due to oxygen by comparing their wave-lengths with that of the auroral line determined by Babcock.

R. J. N.

U.R.S.I. Meeting in October

A meeting of the Canadian National Committee of the International Scientific Radio Union (U. R. S. I.) is to be held jointly with the U. S. A. National Committee of U. R. S. I. and the Professional Group on Antennas and Propagation of the Institute of Radio Engineers, on October 5, 6, 7 and 8, 1953 at Ottawa. The hosts at this first joint U.S.A. and Canadian meeting of these organizations are the National Research Council and the Defence Research Board.

J. H. Chapman

NOTES FROM OBSERVATORIES

Dominion Observatory, Ottawa

New equipment at the Dominion Observatory includes two crystal clocks, one for the Time Service, the other a compact unit with a range of frequency outputs from 10 megacycles to 60 cycles, belongs to the Gravity Division. Stellar Physics recently took delivery of a Mann two-co-ordinate plate measuring machine having a range of 250 mm. by 265 mm. The Magnetic Division has a new Ruska variometer for recording H, D, and Z components. P.Z.T. observing has been made easy with a programme observing machine which uses punched film to time the operations. CHU time signals have been improved with a new antenna array on each frequency, and an increase in power on 7335 kilocycles from 0.3 to 3 kilo-watts by reason of a new Collins transmitter.

The magnetic laboratory has moved from the basement of Observatory house to spacious quarters about a mile away. A new caretaker's residence has been added to the Magnetic and Meteor observatories at Meanook, Alberta, and occupied by Mr. and Mrs. O. Larsen and their two children.

Matrimony has caught up with three staff members, Miss Delma Cochrane and Mr. Ronald Niblett, who have established a home together, and Miss Faye Lutes who is now Mrs. J. McNeil. There are a number of new summer appointees, but it is pleasant to greet again Mrs. L. Herzberg of Ottawa, and Dr. Allan Cook of Harvard. Prof. Edward Kennedy, Physics Department, University of New Brunswick, is also here for the summer. Dr. P. L. Willmore returned to Ottawa at Easter, having completed his part in a volcano research project for the British Colonial Office in the West Indies and Lesser Antilles. Five of eight seismic stations were established, and a preliminary thermal survey concluded.

A programme of meteor photography using two Super Schmidt Cameras is operating at Meanook and Newbrook, Alberta. One of three meteor spectra recently secured (using a grating in conjunction with an f2.5 lens) shows better detail than any spectrum hitherto obtained.

A gravity survey of the Malagash area was recently done for the Nova Scotia Department of Mines. Field parties of the Gravity Division are extending the Mexico-to-Canada chain of basic pendulum stations northward to Alaska, while gravimeters are being used to tie in the network of eastern and western Canada. The Magnetic field parties are operating

along the American border, in the Ungava area, and up the Labrador coast to Resolute Bay.

During March Dr. Beals visited Washington, Paris, London, and other scientific centres in the British Isles. He had many useful discussions with eminent scientific people, and also attended meetings of both the Royal Society and the Royal Astronomical Society.

He studied the British ring crystal type of frequency standard, the British and French talking clocks, and the latest developments in meridian circle telescopes. With Dr. R. A. Smith of the Telecommunications Research Establishment, he studied the latest type of far infra-red detectors, and made arrangements for the use of similar equipment at the Observatory. Remanent magnetism is being studied in three British and one French institution and the methods used were investigated in connection with a possible Canadian contribution to the study.

Two formal papers were presented, one at the Institute d'Astrophysic de Paris (in French) entitled "Celestial Emission Line Objects of Early Type". The other by Beals and Oke, "On the Relation between Distance and Intensity for Interstellar Calcium and Sodium Lines," was presented at a meeting of the R.A.S., at which time Dr. Beals was also invited to report generally on work at the Dominion Observatories. A personal honour was the induction of Dr. Beals as a member of the Royal Society, at a meeting which was notable by the presence of the Duke of Edinburgh who has taken a very personal interest in British science and scientific institutions during the past few years.

MEETINGS OF THE SOCIETY

AT TORONTO

November 4, 1952.—The meeting was held in the McLennan Physics Laboratory. The President, Mr. F. L. Troyer, was chairman.

The following were elected to membership in the Society (from Toronto unless otherwise stated): F. M. Bateson (Rarotonga, Cook Islands, South Pacific); Wilmot B. Reilly; Nathan Shaul; Henry Storrison (Scarboro Junction); S. C. Venter (Pretoria, South Africa).

It was moved by Adam Bell and seconded by G. Dale that Miss R. J. Northcott, J. F. Heard and Frank Publow should form the nominating committee for the next slate of officers to be elected December 2nd.

The first part of the evening's programme consisted of questions and answers. Several of the members had submitted questions and these were supplemented by questions from the floor. It was found necessary to hold over some of them until the next Member's meeting.

The second part of the programme was a showing of the film "Weather Whys" through the courtesy of the Meteorological Office. Although the theme of the picture was weather and its effect on farming, there was much to interest the astronomer, whose career also depends, at least partially, on weather conditions. Instruments for measuring pressure, humidity and wind velocity were shown as well as schematic diagrams of the earth's atmosphere. The most interesting part of the atmosphere as far as the weather man is concerned is the troposphere, the region just above the surface of the earth where the clouds form. Perhaps the most interesting thing as far as the layman was concerned was the visual description of cyclones and typhoons, with all too realistic scenes of the chaos they had created. Since weather is the most frequent topic of conversation, the members had not only an educational evening but a practical one.

November 18, 1952—The meeting was held in the McLennan Physics Laboratory. Mr. F. L. Troyer, President, was chairman.

The following people were elected to membership in the Society (from Toronto unless otherwise stated): Robert A. Ballantyne (Kleinburg), Sean F. O'Gorman, R. Edmund Raymer, Jaromyr Sabat, Maurice D. Smith.

Miss Northcott presented the report of the Nominating Committee.

The speaker of the evening, Dr. J. F. Heard, Director of the David Dunlap Observatory and Head of the Department of Astronomy, University of Toronto, was introduced by the President. The title of Dr. Heard's address was "An Astronomer's Pilgrimage to Rome".

The purpose of Dr. Heard's trip to Rome was to attend the Eighth General Assembly of the International Astronomical Union as a Canadian delegate. The I.A.U. was founded in 1919 to facilitate the passage of ideas between different countries and to advance the science of astronomy. Each country has its own

National Committee of the I.A.U. and in this country there are about twenty members. From the 35 countries that belong to the I.A.U. a good many hundreds of delegates attended the General Assembly, which meets every three years. There are 42 Commissions in the I.A.U., each dealing with a special branch of astronomy, and each Commission having members who are specialists in that particular field. The General Assembly enables these Commissions to discuss their problems, and each Commission presents a report to the General Assembly.

One of the most interesting problems discussed at this Assembly was that of stellar evolution. The Russian delegates, headed by Ambarzumian, had several new ideas to put forth. The basis of their argument is found in the recently-discovered "star associations". That is, certain areas of the sky seem to favour stars of a certain kind. There are two types of associations, the O-associations containing hot blue giants and the T-associations containing yellow, dwarf, variable stars, known as T-Tauri type stars. These associations are of the order of 600 light-years across. So far, about 25 associations of each type have been found. Ambarzumian predicted that these associations would be unstable and that they must be flying apart, and this was verified at least in the case of Perseus II by the Dutch astronomer Blaau. The rate was found to be 6."0027/degree/year. From this number the age of the association can be calculated, and the result is about 1.3×10^6 years. Since the age of the earth is believed to be around 3×10^9 years, the association must be comparatively new. On this theory, the Russians believe further that the O-association stars become cooler, during which process they lose considerable mass through corpuscular radiation. In the case of the sun, it lost about 20 per cent. of its original mass while cooling down. As for the T-associations, they are feeding in ready-made dwarfs.

Dr. Heard illustrated his lecture with beautiful coloured slides, both astronomical and non-astronomical. They had been taken in England, France and Italy.

An informal thanks was given to Dr. Heard by the hearty applause of the audience.

December 2, 1952–The meeting was held in the McLennan Physics Laboratory with Mr. F. L. Troyer, President, in the chair.

There was one election to membership from a nomination of Nov. 18, 1952. This was Maxwell Beckett, Dunnville. However, on a motion by Miss R. J. Northcott, By-Law II was suspended and the following people were also elected (from Toronto unless otherwise stated): D. J. Gwilliam (Oshawa); J. L. Gwilliam (Oshawa); Barry O'Neill; G. O. Philip; A. J. Pratt (Peterborough); Paul Sutherland; Jaan Teng (Lorne Park); W. J. Wright.

The meeting was under the charge of the Amateur Telescope Makers group who had brought an interesting display of telescopes, optical and mechanical parts for the occasion. Mr. Bud Clarke took over the chairmanship, and gave an account of the processes involved in "Grinding a 6-inch Mirror". He also described various types of mountings.

Next Mr. A. G. Cooper discussed "Stereographic Photography of the Moon", which depends on the principle of parallax. Ordinarily, when we look at the moon, the surface looks flat because our eyes are close together and we have no sense of distance. Stereoscopic vision retains the shape of the object so the moon looks round. Libration in longitude of the moon provides an opportunity to take pictures of the same point at the same illumination but at two different angles. The method was explained and it was shown how it could also be applied to Jupiter.

Mr. Paul Sutherland showed some excellent slides of his progress in polishing and grinding a 6-inch mirror, and this was supplemented by a verbal account of the trials and tribulations of a telescope maker as experienced by Mr. S. Cranswick and Mr. V. Ramsey.

Another of the interesting features of this meeting was an exhibit of oil paintings by Mr. R. Broadfoot. These were excellent portrayals of the Andromeda nebula and other famous astronomical "scenes".

February 10, 1953—The meeting was held in the McLennan Laboratory. The president, Dr. R. E. Williamson, was in the chair.

The speaker, Dr. Andrew McKellar, of the Dominion Astrophysical Observatory, Victoria, B.C., was introduced by Dr. Williamson. The subject of his lecture was "Probing the Atmospheres of Supergiant Stars".

Eclipsing binary stars give an opportunity of studying the effect of the light of one star on the atmosphere of the other during partial eclipse. Four special cases of eclipsing binary stars were discussed: Aurigae, VV Cephei, 32 Cygni and 31 Cygni. For each of these stars the spectrum of both components is observed, one component being a small hot star and the other component being a giant cool star. Dr. McKellar discussed 31 Cygni in some detail. This star had been observed at Victoria and Ann Arbor during the recent 1951 eclipse. The spectra showed very complex variation in the structure of the lines during the partial phase, when the light from the hot star passed through the outer atmosphere of the giant star. The interpretation of these changes is that there must be large motions of gas in the giant atmosphere, something analagous to solar prominences, but on a larger scale. (An article on this subject will appear in a later JOURNAL.)

Dr. Heard expressed the appreciation of the members of the Toronto Centre for this very interesting lecture by a fellow member of the Society.

February 24, 1953—The meeting was held in the McLennan Physics Laboratory. The First Vice-President, Mr. W. R. Hossack, was in the chair.

The following were elected to membership in the Society (from Toronto unless otherwise stated): Norman T. Barratt, Noel Bates, Harold L. Bayham, William R. Brown (Rosslyn, Va.), W. Edwin Farrow (Oshawa), Stanley Karas, Harry W. Keller, Philip W. Locke, Ralph F. Pearce, Ronald Pelham, Ralph H. Raymer, Victor J. Westbrook, Edwin B. Weston. Mr. Robert M. James was transferred to the Toronto Centre.

The meeting was turned over to Mr. Bud Clarke, Director of the Amateur Telescope Makers Group. Mr. Clarke acted as chairman and introduced three speakers from the group who spoke on the various phases of "Telescope Making".

The first speaker was Mr. Raymond Broadfoot, who described the optical side of telescope making. He gave the specifications of the material that would be required to grind and polish a 6-inch mirror and demonstrated the different techniques needed at various stages. He also described the methods of testing the mirror for focal length and later in the work, of using the Foucault test to determine the exact shape of the mirror.

The second speaker was Mr. Norman Duhig who undertook the description of the mount and its requirements. There are three components of a telescope mount. First the tube must be made to accommodate the mirror cell, the eyepiece and the prism with its spider and yet at the same time be strong, rigid and light. In the mounting

section, again rigidity is the most important consideration, and amateurs find that plumbers' supplies offer a good selection of elbows and other fittings. Finally there is a tripod to worry about, and here, even more so than in the rest of the mount, rigidity is essential.

Finally, Mr. Tim Cooper discussed the uses of a telescope, and its limitations. For instance the resolving power is limited by the phenomena of interference. Mr. Cooper mentioned the various objects that could be seen to advantage with a 6-inch telescope and pointed out the applications of photography.

Tuesday, March 10– The meeting was held in the McLennan Physics Laboratory. Dr. R. E. Williamson, President, was in the chair.

The following people were elected to membership in the Society (from Toronto unless otherwise stated): Miss Irene Adams, Fred Andrew, James A. Bartlett, Stanley Biggs, Frank R. Carrington, Albert Cooper (Port Credit), Hugh R. Dignam (Sutton West), J. Holosko, Tony Hyrnick, Ralph Jantzi (Wellesley), Miss Bessie Lawlor, John A. Marshall (Oshawa), Edward R. Wilbee.

The speaker, Dr. Nancy G. Roman of the Yerkes Observatory, University of Chicago, was introduced by Dr. Helen S. Hogg. The subject of Dr. Roman's address was "We Get to Know the Milky Way—How Astronomers Learn about our Galaxy".

Herschel was the first to study galactic structure in 1784. His theory was based on the assumptions that all stars had the same intrinsic brightness and that the density of stars was uniform up to the boundary of the galaxy. At this time there was no scale of distances. In 1900 Kapteyn proposed a model based on the study of proper motions of the stars and their spectral types. Shapley, in 1918, suggested a model that put the centre of the distribution of globular clusters at the centre of the galaxy. This meant the dimensions of the galaxy were much greater than those proposed by Kapteyn, and the idea of a local system was developed to reconcile the two models.

Further help came from the discovery and interpretation of interstellar absorption. By studying the effects on the distribution of extragalactic nebulae and other objects, it was possible to introduce a new model. Galactic rotation was also helpful here, when such objects as high-velocity stars were studied, and star streaming discovered. When a comparison of extragalactic nebulae was made, the Andromeda nebula was found to resemble our own as far as the data could tell.

During this time there had been made extensive observations of the structure of our own Milky Way. The patchy areas had been observed, the existence of globules verified, and in 1936 Beals had discovered multiple interstellar lines, indicating the presence of more than one obscuring cloud in the line of sight, each with its own velocity. During the war, the Andromeda nebula was resolved and two types of populations were recognized. A closer look was made at our own galaxy, and it revealed the presence of the same two types of stars. By realizing that the Andromeda nebula and our own galaxy were comparable, many of the problems of our Milky Way were solved.

Just recently new developments have thrown further light on the structure of the galaxy. This, of course, is radio astronomy, and it is hoped that many more problems will disappear by this powerful approach.

Dr. Roman concluded her lecture by summarizing the progress of the past few years, and the picture this progress now gave us. However, in spite of this great step forward, there are still enough problems to be solved in the future to keep astronomers occupied for some time.

Miss Ruth J. Northcott thanked Dr. Roman for her interesting lecture on behalf of the Toronto Centre.

Tuesday, March 24—The meeting was held in the McLennan Physics Laboratory with the First Vice-President, Mr. W. R. Hossack, in the chair.

The following people were elected to membership in the Society (from Toronto unless otherwise stated): H. A. Chapman (Uxbridge), A. Francis, C. F. Hutchinson, K. M. Langmuir, T. E. Pituch, H. A. Preston, V. H. Richardson, Miss A. J. Rowell.

Mr. Hossack gave a short talk on the origin and meaning of stellar spectra. He described what is meant by wave-motion as applied to light and pointed out that different regions of the spectrum correspond to different wave-lengths. He also discussed Kirchhoff's three laws of spectroscopy.

Next Mr. Hossack described the Bohr model of the atom, and related the description to conditions in stellar atmospheres. He illustrated the lecture with slides, and of particular interest was the one showing the series of spectra as it changes throughout the stellar sequence. Mr. Hossack pointed out how this could be interpreted as a temperature sequence.

Finally Mr. Hossack discussed the way in which radial velocities of stars are determined, particularly with reference to binary systems.

After a short discussion on what to do with a completed telescope, the meeting was adjourned.

BARBARA CREEPER, *Recorder.*

AT WINNIPEG

November 12, 1952.—The regular meeting was held at 8.30 p.m. in the lecture room of the Grain Exchange Building. Nineteen members and guests were present. Mr. D. R. P. Coats was in the chair.

A letter was received from Toronto requesting that we appoint a member from our section to the National Council. As Mr. Rasmussen was making a trip to the East it was unanimously agreed that he should represent the Winnipeg Centre.

The meeting appointed a nominating committee to serve in the selection of officers for the forthcoming year. Members of the committee are: Miss Muir; Mr. T. R. McKintosh; and Mr. Charles Card.

Miss Alice Armstrong gave a short lecture on some salient features of "The Moon." She gave specific names and details of the dark patches or seas that are observed on the moon's surface. It was pointed out that there were some 30,000 craters, some of them having a depth of 20,000 feet. Also large mountain peaks reaching 26,000 feet high. Some of the more important ranges are named after our mountain ranges, Alps, Carpathian, etc.

The main speaker for the evening was Mr. A. G. Lawrence (writer and naturalist) who spoke on "Bird Migration" with special mention of birds migrating across the face of the moon. Mr. Lawrence introduced his topic by giving interesting anecdotes of ideas of ancient times about bird migration. He then dealt with present day methods of bird watching and bird banding. Special mention was made of the contribution of about 2,000 naturalists who make regular observations and who submit reports to a central body. With the aid of lantern slides he then showed migratory patterns of many species of birds on the North and South American continents. He pointed out that migratory patterns were very complex.

With respect to lunar observations he stated that this field of work was comparatively new and probably had received undue publicity. His own attempts had been unsuccessful but some observers had seen as many as 100 birds in one hour. He hoped that in the near future some sound results would be forthcoming but at present his opinion was somewhat guarded. The members received his talk very enthusiastically and many questions were asked after the lecture. Mr. Lawrence also demonstrated a telescope with special features which was manufactured by the Bausch and Lomb Company. He hoped to use this new instrument for lunar observation during the migrating season.

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(3) Greenwich time (1) + (2)	28	00	00
(4) Sid. advance in 28h		04	35
(5) G. sid. time at 0h (O.H.)	22	27	37
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